Indian Journal of Natural Sciences *www.tnsroindia.org.in ©IJONS*

Vol.9 /Issue 51 / December / 2018 *International Bimonthly* *ISSN: 0976 – 0997*

REVIEW ARTICLE

Spectral Multi-Wavelength Properties of a RBSC-NVSS Observation for a Sample of Active Galaxies

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Received: 23 Aug 2018 Revised: 25 Sep 2018 Accepted: 27 Oct 2018

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ABSTRACT

We report a statistical analysis of samples of galaxies with active galactic nuclei (Seyferts 1, Seyferts 2, and quasars) taken from ROSAT Bright Source Catalogue (RBSC) and the NRAO VLA Sky Survey (NVSS) of bright X-ray galaxies. We investigate multi-wavelength observations including in the radio (1.4 GHz), the blue optical (4400 A^0) and the X-ray (0.1-2.4 keV) bands. For Seyfert 1 galaxies the results of a statistical analysis shows that there is a strong correlation between the quantities ($L_{X-ray} - D$ and $L_{1.4} - D$ correlations), and the slopes of the relation($L_B - D$) are flatter than the slope of 0.5 expected for cosmologically nearby objects, while for Seyfert 2 type galaxies, we find that a very strong correlation between relation($L_{X-ray} - D$ and $L_B - D$), which indicates that, the Seyfert 2 have active components unrelated with the radio emission compared to Seyfert 1. We also found that, the Seyfert 1 and 2 galaxies show a strong linear relation between ($L_{X-ray} - D$), which could be related to the presence a very high X-rays emission in broad emission lines in their nucleus. The slopes of the relation between the X-ray emission and distance galaxies for QSO galaxies are significantly steeper than radio continuum, blue emissions and distance (slope ~ 1) with probability of chance correlation, $P < 10^{-7}$. We can conclude that, the presence of a large star formation activity in these galaxies depends linearly on the correlations between galactic luminosities and distance. At large distances this effect may be dominant.

Key words: Galaxies: Nuclei – Radio continuum: galaxies – Techniques: spectroscopy, Active galaxies: Seyfert – Quasars.

INTRODUCTION

In gernral the emission-lines that lay on the spectra of active galaxies can divided into two main types: First type is broad emission-line which can be broad up to ~$10000\ \mathrm{km\ s^{-1}}$, due to the Doppler broading effect, in addition, such an emission-line are mainly related to Seyfert galaxies type 1 and QSOs, or quasistellar objects. Second type is narrow emission-line which has width of ≤ $1000\ \mathrm{kms^{-1}}$, and such an emission-line are mainly related to Seyfert galaxies type 2.

Since the late of the last century till now, many paper had deals with galaxies that has active galactic nuclei host in the center of these objects. Some of those papers studied the nature of these sources via using spectroscopic and photometric data [1-4]. Other projects studied the physical properties of active galaxies by using different wavelength (X-ray, Radio, Infrared, Ultraviolet, and Optical) observations [5-8]. One of these properties is the relation between luminosity (L) and redshift (z). Where in the eighth of the last century some paper have been appeared to clarify this relation (L-z), and find how much these parameters are correlated[9] had studied 273 objects of active galaxies divide to (235 Quasars and 38 Seyfert-1 galaxies) via using X-ray radiation, and they found that there is a linear regression line between the X-ray luminosity L_{X-ray} an redshift for these samples following this formula: $\log L_{X-ray} = 41.2 + 1.5 \times \log z$ and the coefficient correlation is R=0.905. Following the last paper [10] studied the extragalactic objects at different redshift and they conclude that there is a linear behavior between the L_{X-ray} and z for the high redshift sources, except some galaxies clusters. Some authors[11] studied a survey (Spitzer Space Telescope imaging surveys) for a large numbers of AGN sources and they plot between the luminosity at $5\mu m$ and redshift and they confirm the linear correlation between these two parameters.

In this work we plot between the luminosities (Radio, Optical, and X-ray) and distance instead of redshift for Seyfert galaxies (type 1 and 2), becuase these objects are kind of close to us $(0.0024 \le z \le 0.818)$ therefore the relation between the distance and redshift are directly proportional. For the QSOs we plot between the luminosities (Radio, Optical, and X-ray) and distance, as well as, between the luminosities and redshift, becuase for these sources the redshift was increase from low to high values $(0.09 \le z \le 3.27)$, therefore the relation between the distance and redshift are not directly proportional for all QSO galaxies.

The details of the samples that we deals with in this project, as well as, the numbers of these sources has been mentioned in section 2. Furthermore, the mathematical methods that has been used to derive the equations that employed in this paper, in addition to the derivative of the parameters are mentioned in section 2. The statistical analysis of the samples, as well as, the correlation between the luminosities and distance and between luminosities ration and absolute magnitude are present in section 3. Finally, the discussion and conclusions follows in section 5.

THE SAMPLE, DATA USED, AND DERIVATION OF PARAMETERS

In this paper we report on a statistical analysis of a sample of (AGNs) of Seyfert galaxies (Sy1 and Sy2 Seyfert galaxy, emission-line spectra classified from type 1 to 2) and Quasars selected from an RBSC-NVSS sample. [12] have cross-identified the ROSAT Bright Source Catalogue (RBSC) and NRAO VLA Sky Survey (NVSS) to construct an RBSC-NVSS sample. On the basis of the RBSC-NVSS sample [12] , we have selected a sample of number (315) of Seyfert galaxies type (Sy1), number of (32) type (Sy2), and number of (97) Quasars type (QSO).

The luminosity $L[E_1, E_2]$ in the energy bands E_1, E_2 is given by [13,14]:

$$L[E_1, E_2] = 4\pi\, K_{corr}(z)\, D_{bol}^2(z)\, f[E_1, E_2] \qquad (1)$$

where $K_{corr}(z)$ is the K-correction term, $D_{bol}(z)$ is the bolometric luminosity distance term, $f[E_1, E_2]$ is the observed flux density in the energy band $[E_1, E_2]$, and z is the redshift. The $K_{corr}(z)$ are given by [13]:

$$K_{corr}(z) = (1+z)^{-(1+\alpha)} \qquad (2)$$

and the bolometric luminosity distance $D_{bol}(z)$:

$$D_{bol}(z) = \frac{2cz}{H_0\ (G+1)}\ [1+\frac{z}{1+G}]\quad [\mathrm{Mpc}] \qquad (3)$$

Where

$$G = \sqrt{1+2q_0} \qquad (4)$$

If density parameters $(\Omega_M, \Omega_\Lambda, \Omega_k)$ = (1, 0, 0), then the deceleration parameter $q_0 = 0.5$ [15].We calculated the optical (L_B), radio ($L_{1.4}$) and X-ray (L_{X-ray}) luminosities from the respective formula:

$$\log L_B = 23.70 + 2\log D_{bol} - (1+\alpha_B)\log(1+z) - 0.4 m_B \qquad (5)$$

$$\log L_{1.4} = 17.08 + 2\log D_{bol} - (1+\alpha_{1.4})\log(1+z) + \log f_{1.4} \qquad (6)$$

$$\log L_{X-ray} = 16.50 + 2\log D_{bol} - (1+\alpha_{X-ray})\log(1+z) + \log f_{X-ray} \qquad (7)$$

Where L_B and $L_{1.4}$ in the unit of $[\mathrm{W.Hz^{-1}}]$, and L_{X-ray} in unit of $[L_\Theta]$. Futhermore, m_B is represent the blue magnitude at 4400Å blue-band. $f_{1.4}$ and f_{X-ray} are the radio emission flux density at 1.4 GHz in unit (mJy[1]), and X-ray flux density in the soft X-ray band of (0.1 - 2.4 KeV) in units of $[\mathrm{erg\ cm^{-2}\ s^{-1}}]$.

We assume energy index for X-ray band $\alpha_{X-ray} = -1.02$, the optical bands $\alpha_B = -0.5$, and for the radio continuum $\alpha_{1.4} = -0.8$ [16] for the Seyfert galaxies types (Sy1 and Sy2). For Quasars type, the energy index α (from optical to X-ray bands) taken to be - 0.5 [13] For Friedman cosmology and assuming the Hubble constant $H_0 = 70\ \mathrm{km\ s^{-1}\ Mpc^{-1}}$.

In [12] besides X-ray and radio densities flux data, the blue magnitudes, redshifts, and AGN types are also presented. For statistical investigation of the multi-frequency properties of AGN, specifically Seyfert galaxies (Sy1 and Sy2) and Quasars, the RBSC-NVSS sample provides an exceptional opportunity for a detailed study. According to equations

[1] $1\ \mathrm{Jy} = 10^{-23}\ \mathrm{erg\ cm^{-2}\ s^{-1} Hz^{-1}}$

(3,5, 6, and 7), we havecomputed all redshifts, and AGN types are also presented. For statistical investigation of the multi-frequency propertlated average parameters of Seyfert (Sy1 and Sy2) and Quasars galaxies. Table 1 presents the results of these calculations.

STATISTICAL ANALYSIS AND LUMINOSITY-DISTANCE CORRELATIONS

Investigation of an unbiased sample of active galaxies with comprehensive observationaldata on relevant parameters at different wavelengths is essential for a statistically reliable test, for understanding the different physical conditions in these objects, and to test the unification model.

For each sample of AGN galaxies (Sy1, Sy2, and QSOs) we have calculated all correlation coefficients between luminosities from (radio to X-ray) band, including distance. As a result, this procedure significantly reduced the artificial correlations between luminosities and distances caused by the fact that at large distances we observe the more powerful sources. We selected only those pairs of variables that which showed significant correlations $(P < 0.01)$. Then we performed a multiple regression analysis to comprehend more about the relationships between the parameters that involved.

In this paper we used statistical program (statistic-win-program) to find whether there is a correlation relation between many parameters such as luminosities and distance . Also we used various regression to get the graph between these parameters and calculation the significance levels (P) beside the coefficient partial correlation (R). The aim of the linear reduction method is to fit a convenient line out of the points. Precisely, the code will calculate a line so that the deviations squared detected points from that line will be minimized. Generally, this method occasionally referred to as linear least squares approximation. Generally, a various regression procedure will determine the linear formula of the form:

$$Y = a + b_1X_1 + b_2X_2 + ... + b_nX_n \qquad (8)$$

Where Y represent the dependent variable, and the independent variables are represented by X_1, X_2, ..., X_n, as well as, b_1, b_2, ..., b_n represents the slopes that used as retraction coefficients. Finally, a is regarded as the intercept. Note, the dependent variable that predicted by the independent variables are refers to the retraction coefficients that contribute independently in each independent variables. To give an example about what has been mention before or explain in another way: that means the variable Y is correlated with the variable X [16,17]. We have applied this technique for the samples of Sy1, Sy2 and QSOs galaxies.

RESULTS

In this project the investigation of multi-wavelength observational radio, blue and X-ray properties of AGNs (Sy1, Sy2 and QSO) led us to the following results:

$1-$**For sample of number (315) of Seyfert galaxies (Sy1 types) we have data analysis (see Table2) and relation (Luminosity - Distance)**:

$$\log L_{1.4} = (0.66 \pm 0.05) \log D + (0.20 \pm 0.05) \log L_B + (9.10 \pm 2.10)$$

$$\log L_{X-ray} = (0.78 \pm 0.04) \log D + (0.16 \pm 0.04) \log L_B + (2.00 \pm 1.05)$$

$$\log L_B = (0.35 \pm 0.09) \log D + (0.30 \pm 0.08) \log L_{X-ray} + (0.21 \pm 0.06) \log L_{1.4} + (16.6 \pm 0.60)$$

2 − **For sample of number (32) of Seyfert galaxies (Sy2 types) we have data analysis as shown in Table 3and relation (Luminosity - Distance):**

- $\log L_{X-ray} = (0.78 \pm 0.10)\log D + (0.28 \pm 0.11)\log L_{1.4} + (0.30 \pm 0.10)\log L_B + (12.60 \pm 3.90)$
- $\log L_B = (0.78 \pm 0.28)\log D - (0.79 \pm 0.27)\log L_{X-ray} + (0.70 \pm 0.16)\log L_{1.4} + (15.7 \pm 1.84)$

3 − **For sample of number (97) of Quasar's (QSO types) we have data analysis as present in Table4 and relation (Luminosity - Distance):**

- $\log L_{X-ray} = (0.85 \pm 0.08)\log D + (5.73 \pm 1.16)$
- $\log L_B = (0.65 \pm 0.16)\log D + (16.50 \pm 1.16)$
- $\log L_{1.4} = (0.42 \pm 0.18)\log D + (11.40 \pm 4.03)$

4 − **The relation between luminosities and redshift (z) for QSO active galaxies is given by:**

- $\log L_{X-ray} = (0.682 \pm 0.078)z + (7 \pm 1.43)$, N=95, $R_z \sim 0.67$, $P < 10^{-7}$
- $\log L_B = (0.36 \pm 0.14)z + (0.200 \pm 0.096)\log L_{1.4} + (16.5 \pm 2.10)$, N=95, $R_z = 0.25$,

$P \sim 10^{-2}$, $R_{1.4} = 0.21$, $P_{1.4} = 4 \times 10^{-2}$.

DISCUSSION AND CONCLUSIONS

In the present work Multi-wavelength observational properties of a RBSC-NVSS sample for (315) Seyfert type 1 galaxies, (32) Seyfert type 2, and (97) Quasars galaxies are studied by means of the statistical analysis. For this we used complete samples of these galaxies as shown in the Tables (2, 3, and 4). In this research, we studied the relations between blue to X-ray luminosities and distances for a different samples of active galaxies. The results of comparison between distance-luminosity have revealed different effects.

The results of statistical analysis for Seyfert galaxies type (Sy1) shown that, there is a strong relation between $\log L_{X-ray}$ and $\log D$, as well as, between $\log L_{1.4}$ and $\log D$, with a positive and a strong correlation coefficient ($R_{X-ray}, R_{1.4} = 0.75, 0.6$ respectively). Futhermore, this correlation has avery strong probability of ($P \leq 10^{-7}$),and the figures (1 and 3) shows that the slope is nearly linear ($L_{X-ray} \propto D^{0.78 \pm 0.04}$, $L_{1.4} \propto D^{0.66 \pm 0.05}$).In relation ($\log L_B$ - $\log D$) there is a clear relation with a positive and clear correlation coefficient ($R_B \approx 0.22$) and a good probability ($P \sim 10^{-4}$) and the figure 2 shows that the slope is a flat (Slope ~ 0.4).

In the relation ($\log L_{X-ray}$ - $\log D$) for Seyfert galaxies type (Sy2), there is a very strong correlation coefficient ($R \approx 0.9$) and a stronger probability ($P \leq 10^{-7}$), while in ($\log L_B$ - $\log D$) there is a clear correlation coefficient, and there is no relation between (Log L1.4 -LogD). The figures (4 and 5) shows that existence a strong linear relation between luminosities X-ray, blue and distance with slope~ 1.

For Quasars galaxies there is a strong intrinsic correlation coefficient ($R_x \sim 0.75$) of the (L_{X-ray} - D) plot and $R_z \sim 0.67$ for relation ($L_{X-ray} - z$), as well as, a very high probability ($P < 10^{-7}$) and a strong linear ($L_{X-ray} \propto D^{0.85\pm0.08}$), while in the relation between radio ,blue emission and distance there is clear correlation coefficient with a good probability and linear relation of the ($L_B \propto D^{0.65\pm0.16}$), while a flat slope < 0.5 between ($\log L_{1.4}$ - $\log D$) and also there is a positive correlation between blue luminosity L_B and redshift with a slope ~ 0.4 ($L_B \propto z^{0.36\pm0.14}$) . The figures (6 - 10) shows that the slopes of the relations ($\log L_{X-ray}$, $\log L_B$, $\log L_{1.4}$ – $\log D$), for QSO type sample.

The results of multiple regression analysis show apparently many main points:

(1) We have found the luminosities range of the extended radio continuum at 1.4 GHz ($L_{1.4} \sim 1.2 \pm 2 \times 10^{23}$ $W.Hz^{-1}$), blue at 4400Å ($L_B \sim 1.1 \pm 2.5 \times 10^{22}$ $W.Hz^{-1}$) and X-ray emission at energy band (0.1-2.4 KeV) of $L_{X-ray} \sim 1.3 \pm 2.2 \times 10^{10}$ L_Θ for Sy1 galaxies, and ($L_{1.4} \sim 1.4 \pm 10^{23}$ $W.Hz^{-1}$), ($L_B = 1.2 \pm 1.4 \times 10^{22}$ $W.Hz^{-1}$), ($L_{X-ray} \sim 1.5 \pm 5 \times 10^{9}$ L_Θ) for Sy2 galaxies , while a high luminosities for QSO objects ($L_{1.4} > 10^{26}$ $W.Hz^{-1}$), ($L_B = 1.2 \pm 2.6 \times 10^{23}$ $W.Hz^{-1}$), ($L_{X-ray} \sim 1.2 \pm 5.6 \times 10^{11}$ L_Θ).

(2) The luminosities (L_{X-ray}, L_B, and $L_{1.4}$) for these active galaxies samples (Sy1, Sy2 and QSO) are correlated with the distances of galaxies. The lack of correlation between radio luminosity and distance for type Sy2 perhaps indicates that the association of X-ray, blue emission with a distance is more fundamental, and possibly the weak correlation between radio continuum and a distance may disappear from multiple regression analysis because of the tight correlation between the X-ray and blue emission with distances.

(3) The slope of the correlation between X-ray luminosity and distances of these galaxies is significantly steeper than others with significance levels (probability of chance correlation, $P \sim 10^{-7}$).

(4) In the stronger linear X-ray, blue and radio emission distance correlation, the increases of the slope relation (L_{X-ray}, L_B, $L_{1.4} - D$), believe that with an increase in the star formation, the retention of cosmic-ray electrons within these galaxies (Sy1, Sy2 and QSO) is enhanced. This means that the X-ray, blue and radio luminosities increase on the biggest distance as these active galaxies type Quasars (QSO). Quasar spectra are corrected for the effect of redshift (z). Since many quasars have a high redshift. This means that according to Hubble's law ($V = H_0 \times D$) these active galaxies are very far away, since it must be very luminous, so we can see it. Our results relative to the strong correlation relationship between X-ray luminosity (L_{X-ray}) and redshift (z) for RBSC-NVSS sample selected AGNs for Quasars galaxies consistent compared with the results of [14] for the SPIDERS (RASS and XMMSL sources)-AGN samples. The reason is that both samples have selected surveys for X-ray bright sources.

It can be concluded from the results of statistical analysis of the multi-wavelength radio, blue to X-ray properties of a RBSC-NVSS sample for active galaxies to the following:

I. There are different behaviors of the X-ray, blue and radio luminosities -to- distance relations of sample (Sy1, Sy2 and QSO) galaxies. Statistical analysis showed that we had the presence of a very strong correlation between X-ray emission and distance and a strong linear with slop~ 1.

II. The joint dependence of X-ray, blue and radio luminosities on the distances for (Sy1) type galaxies are strikingly similar to that which was found for Quasars. This similarity of Sy1 and quasars indicates the close link between these two classes of active galaxies (AGNs). The optical spectra of quasars are analogous to the optical spectra of Seyfert 1 galaxies with prominent wide lines, but weaker narrow lines.

III. The X-ray emission of Sy1 and Quasars galaxies is linked with the blue, extended radio emission as well. Moreover, the slopes of the correlations between the X-ray and blue emission are significantly steeper than that for Sy1 and QSO.

IV. The X-ray, blue and extended radio properties are strongly correlated with distances of these galaxies with a higher star formation activity and depend on increasing frequency and on the type of these galaxies. This means that the artificial correlations between these luminosities and distance, caused by the fact that at large distances, we observe the more powerful sources.

V. An analysis of our data shows that the radio, blue and X-ray luminosities ($L_{1.4}, L_B, L_{X-ray}$) does not depend on the morphological of these galaxies (Sy1, Sy2 and QSO).

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous referees for the helpful suggestions and comments that will help to improve this work.

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Table 1: Mean (Average) Variables and Standard Error for Active type Galaxies

Variable	Sy1	Sy1	QSO
Z	0.1268 ± 0.0084 N = 314	0.1775 ± 0.0370 N = 32	0.6162 ± 0.0523 N = 97
$\log D$	2.4978 ± 0.0280 N = 314	2.2653 ± 0.0947 N = 32	3.3536 ± 0.0337 N = 97
$\log L_{X-ray}$	10.3365 ± 0.0524 N = 314	9.7320 ± 0.1837 N = 31	11.7495 ± 0.0670 N = 95
$\log L_B$	22.4000 ± 0.0386 N = 314	22.1469 ± 0.0840 N = 32	23.4220 ± 0.0730 N = 97
$\log L_{1.4}$	23.2935 ± 0.0797 N = 314	22.9483 ± 0.1586 N = 32	26.0470 ± 0.1220 N = 97

Notes: Where N is the number of active type galaxies for (Sy1, Sy2 and QSO) used in the sample.

Table 2: Partial correlation coefficients (R) and probability of chance correlation (P) between Various Parameters of Seyfert type 1 (Sy1) galaxies, No. of casess valid (N=309).

Parameters	$\log D$	$\log L_{X-ray}$	$\log L_B$	$\log L_{1.4}$
$\log L_{X-ray}$	$R = 0.75$	1	$R = 0.23$	–
	$P < 10^{-7}$	–	$P \sim 10^{-4}$	–
$\log L_B$	$R = 0.22$	$R = 0.21$	1	$R = 0.20$
	$P < 10^{-4}$	$P < 3\times10^{-4}$	–	$P \sim 4\times10^{-4}$
$\log L_{1.4}$	$R = 0.60$	–	$R = 0.22$	1
	$P < 10^{-7}$	–	$P \sim 4\times10^{-4}$	–

Table 3: Partial correlation coefficients (R) and probability of chance correlation (P) between Various Parameters of Seyfert type 2 (Sy2) galaxies, (N=31)

Parameters	$\log D$	$\log L_{X-ray}$	$\log L_B$	$\log L_{1.4}$
$\log L_{X-ray}$	$R = 0.86$	1	$R \sim 0.50$	$R = 0.42$
	$P < 10^{-7}$	–	$P \sim 10^{-3}$	$P = 2\times10^{-2}$
$\log L_B$	$R = 0.47$	$R \sim 0.50$	1	$R = 0.63$
	$P < 10^{-2}$	$P \sim 10^{-3}$	–	$P = 2\times10^{-4}$

Table 4: Partial correlation coefficients (R) and probability of chance correlation (P) between Various Parameters of Quasars (QSO types), (N=95).

Parameters	$\log D$	$\log L_{X-ray}$	$\log L_B$	$\log L_{1.4}$
$\log L_{X-ray}$	$R = 0.75$	1	–	–
	$P < 10^{-7}$	–	–	–
$\log L_B$	$R = 0.40$	–	1	–
	$P < 10^{-4}$	–	–	–
$\log L_{1.4}$	$R = 0.23$	–	–	1
	$P < 3\times10^{-2}$	–	–	–

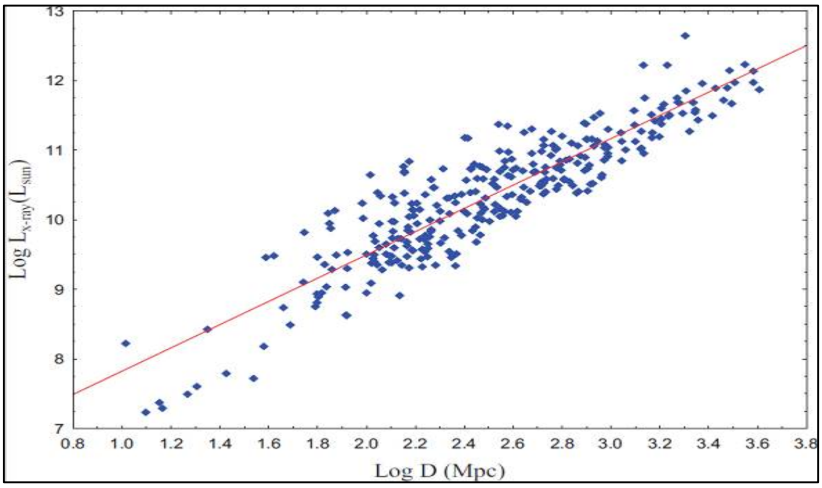

Figure 1: X-ray luminosity as a function of distance for Sy1 galaxies.

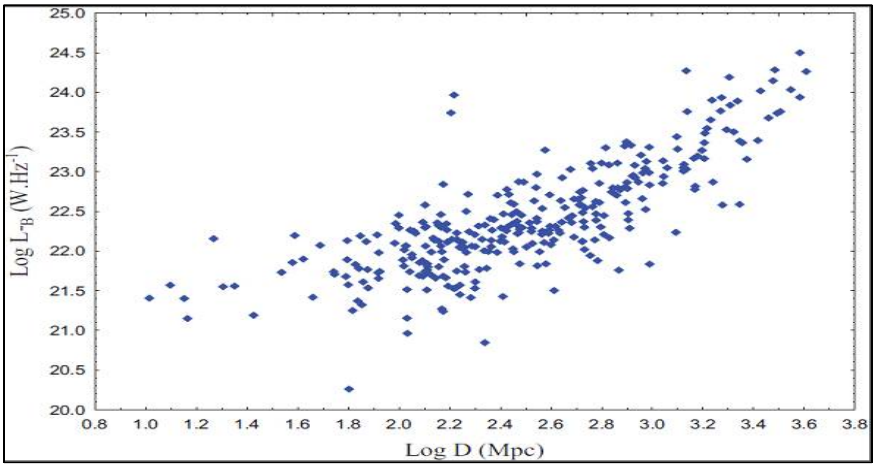

Figure 2: Blue luminosity as a function of distance for Sy1 galaxies.

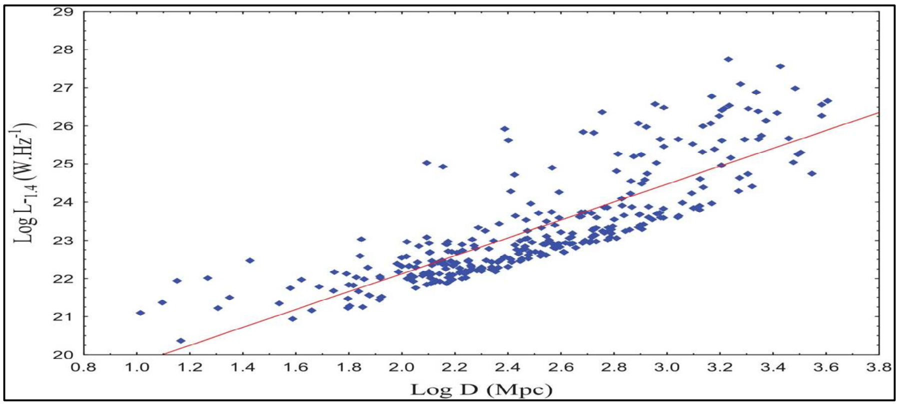

Figure 3: Radio luminosity at 1.4GHz as a function of distance for Sy1 galaxies.

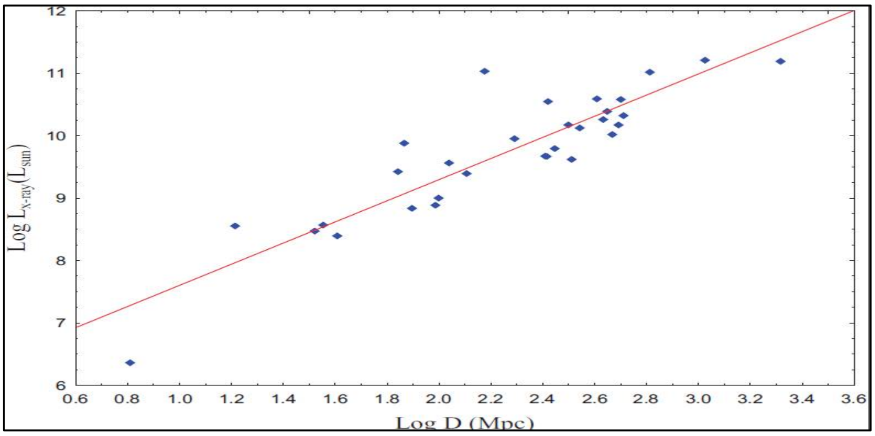

Figure 4: X-ray luminosity as a function of distance for Sy2 galaxies.

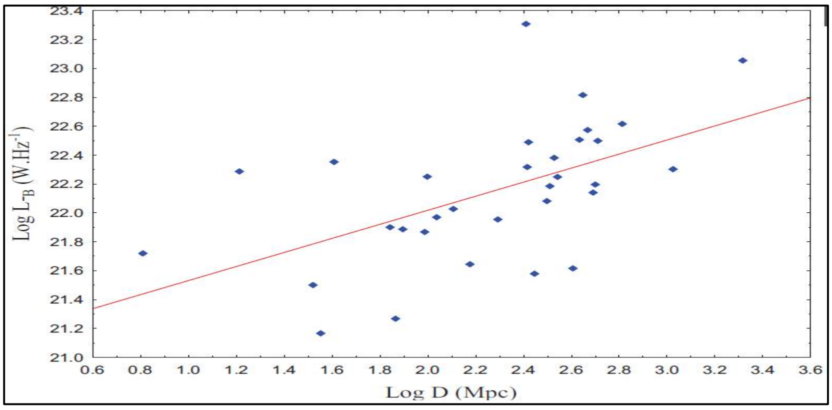

Figure 5: Blue luminosity as a function of distance for Sy2 galaxies.

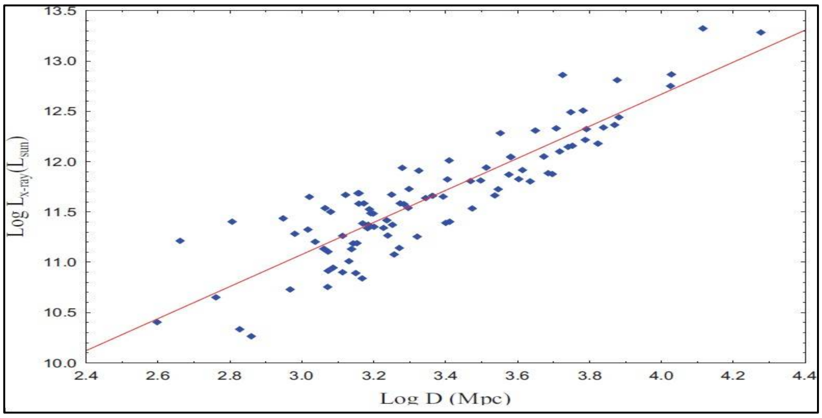

Figure 6: X-ray luminosity as a function of distance for QSO types.

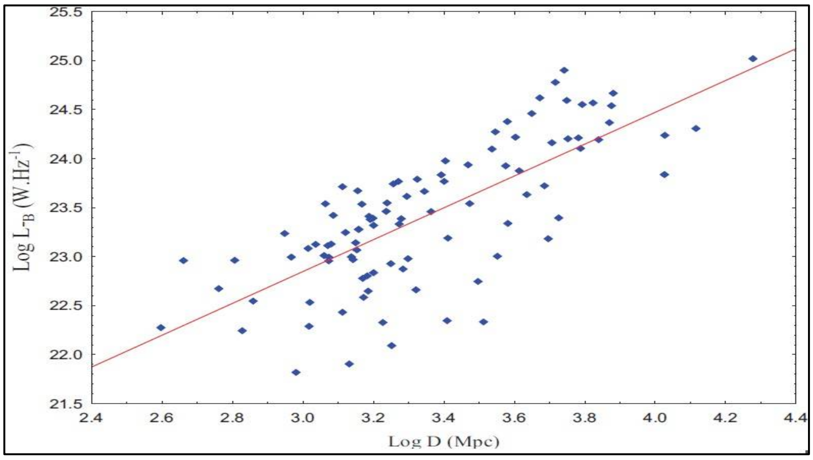

Figure 7: Blue luminosity as a function of distance for QSO types.

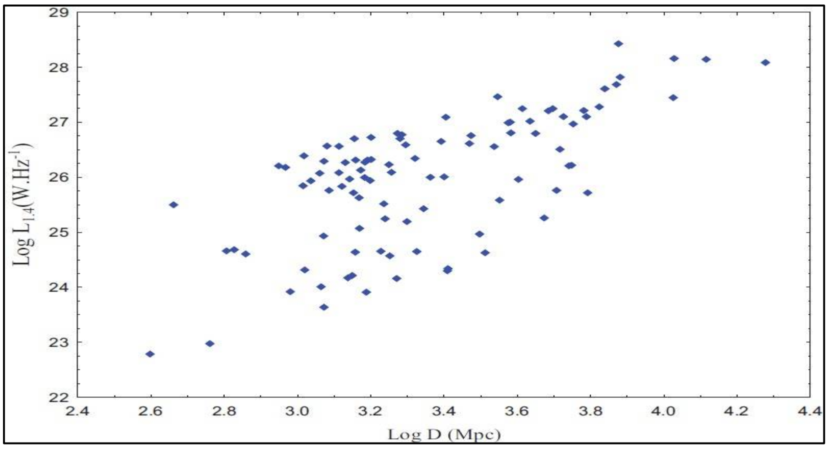

Figure 8: Radio luminosity at 1.4GHz as a function of distance for QSO types.

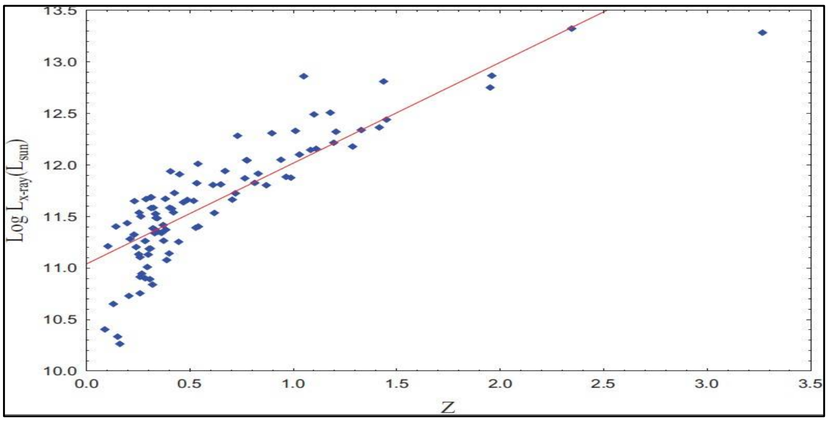

Figure 9: X-ray luminosity as a function of redshift for QSO types.

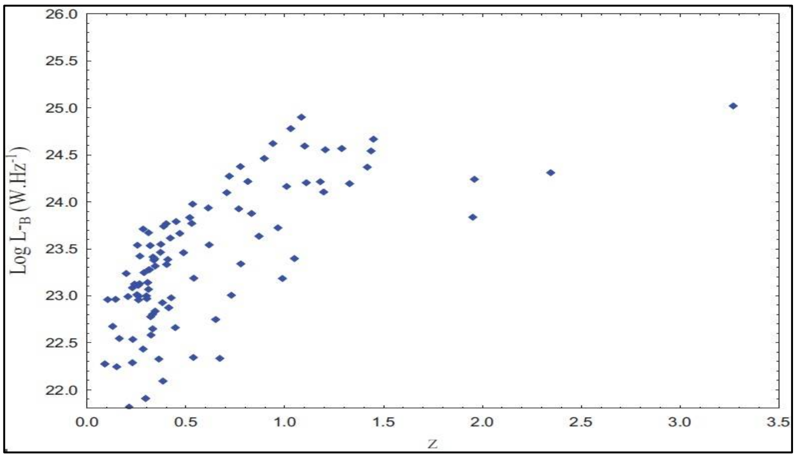

Figure 10: Blue luminosity as a function of redshift for QSO type.